The Top Ten California Floods of the 20th Century

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The purpose of this paper is to summarize the biggest northern California floods of the 20th century. Flooding in California can occur from different causes. At least three types of floods occur:

- Winter general floods, which cover a large area.
- Spring and early summer snowmelt floods unique to the higher-elevation central and southern Sierra Nevada, which occur about once in 10 years on the average.
- Local floods from strong thunderstorms, with intense rain over a relatively small area. These originate in moist tropical or subtropical air and include the flash floods of the desert and other areas of southern California when remnants of eastern Pacific hurricanes get carried into the state.

In recent years, we have also seen intense cells develop at times in the warm sector of major winter storms. An example was the local flooding northeast of Sacramento during January 1995, when up to 6 inches fell in 24 hours.

Flood Factors

The most feared flooding comes from general winter storms covering a wide area. These storms are slow moving, with a long southwesterly fetch extending toward Hawaii, the so-called "pineapple connection" (Figure 1). Often there is a near balance between a high pressure area to the south of California and a strong low pressure area off the northern California or Oregon coast. The greater the pressure difference, the stronger the southwesterly winds, which can reach speeds of 100 km/hr or more at 3000 meters over the San Francisco Bay area. The line of strongest air mass contrast, the frontal zone, can ripple back and forth several hundred kilometers but produces almost continuous rain to fairly high elevations over a broad zone in northern or central California (and less commonly in southern California). This warm southwesterly flow pattern is evident in practically all of our large general floods.

An important factor is the mountain barriers. As moisture-laden air is blown over mountains such as the Sierra Nevada, the air is lifted and cooled with additional rain and snow (Figures 2 and 3). Typically the

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orographic precipitation is 3 to 4 times the amount in the lowlands. For example, the 1600-meter elevation Blue Canyon weather station, northeast of Sacramento, averages around 1600 mm of precipitation per year, about 3.5 times the 450 mm expected at Sacramento, in the middle of the Central Valley. The multiplier ratio on some of the steeper ocean-facing mountain fronts of southern California can be even greater.

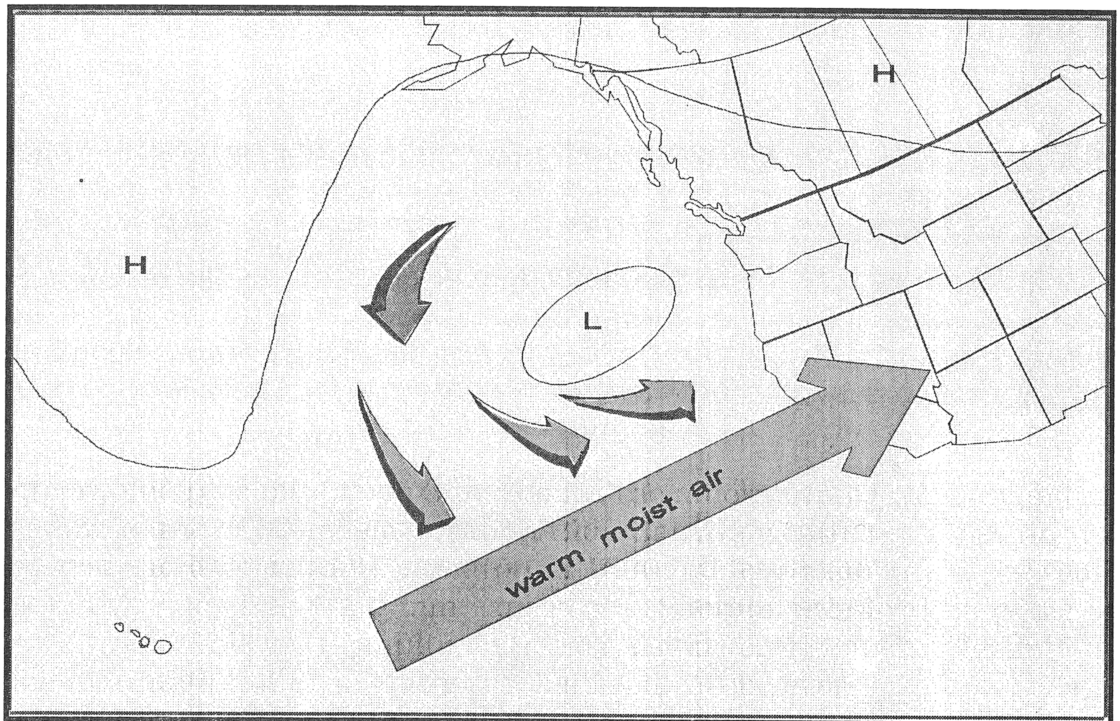

Figure 1. Warm Storm System

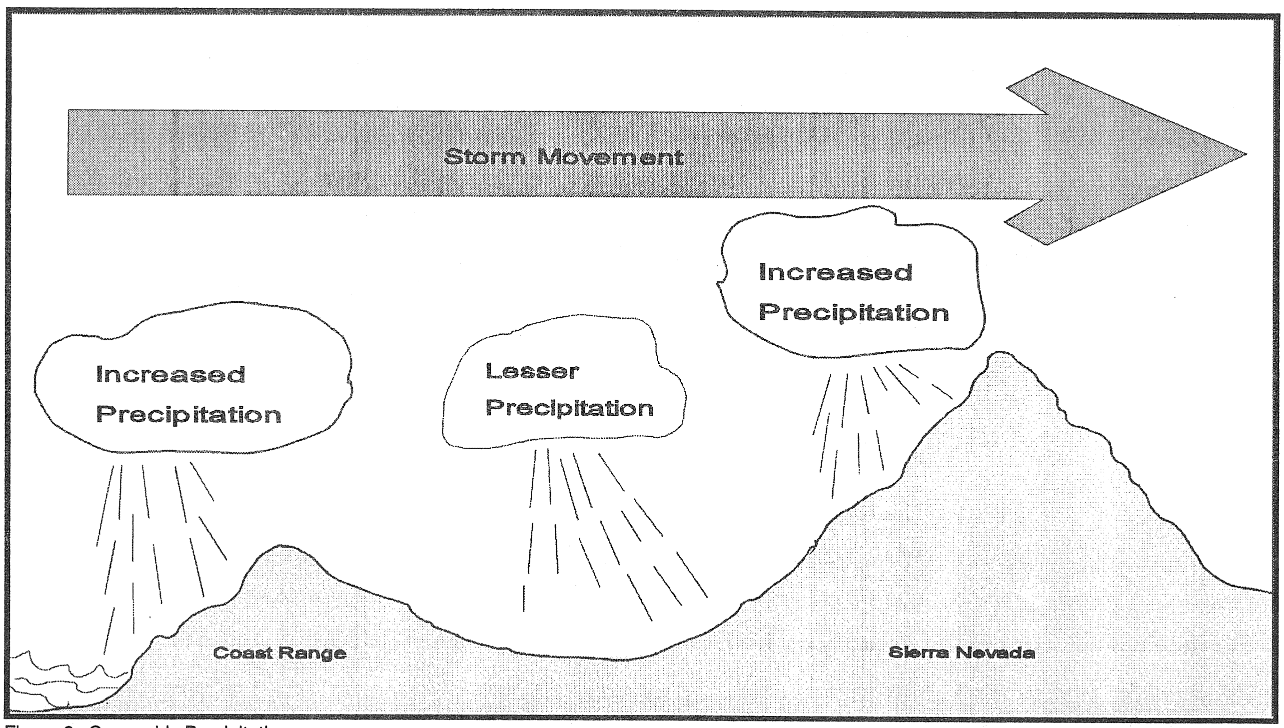

Figure 2. Orographic Precipitation

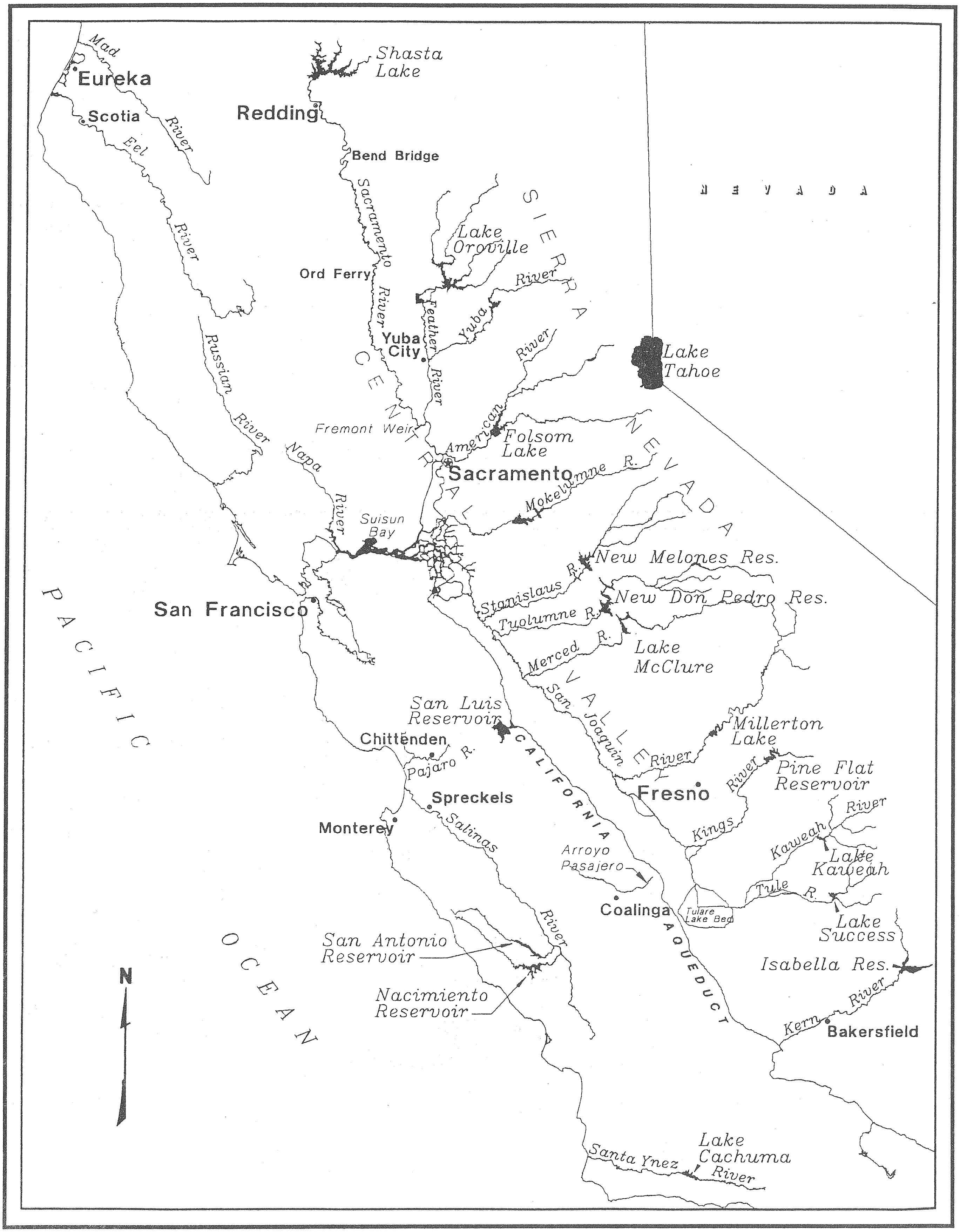

Figure 3. Major Rivers and Lakes in Northern and Central California

The direction of orographic wind flow is important. The greatest amount of water is extracted when the wind flow is at right angles to the mountain barrier, or from the southwest for the Sierra Nevada. A southerly wind direction does not produce such large amounts in the Sierra, but often concentrates precipitation at the north end of the Sacramento Valley, and even the normally rain-shadowed eastern slopes of the northern Coast Ranges if there is a small easterly component. Of course, many storms start out with a more southerly flow during the early phases and shift into a southwesterly and eventually westerly direction as the storm progresses. A west or northwest direction means the flood threat is passing for two reasons: cooler air has less moisture content; and cooler temperatures mean snow at lower elevations, which curtails direct runoff.

A lot of people think snowmelt is the cause of the flooding during the big southwesterly winter storms, but melting snow is only a small portion of runoff during these events, perhaps 10 to 15 percent. Most of the flow is direct rain runoff from intense rain falling to high elevations.

One other factor is necessary to produce large floods in northern California — wet ground, which requires antecedent precipitation. The most striking example is the Columbus Day storm of 1962. This storm produced rainfall comparable to "standard project flood" amounts[1], yet runoff was less than a 10-year annual flood event because the rain fell on dry ground. It produced only a moderate flood, unusually early in the season, but not big enough to make the list of top ten floods.

Folks have generally underestimated the size of the flood threat in our rivers. An exception was John Sutter, who built his Sacramento fort on high ground after ascertaining from the Indians how high the water could get. The early pioneers mostly came from the humid east and just simply couldn't grasp that a river could expand 100 to 1,000 times its low-flow discharge. They just didn't recognize the risk; some say we still don't.

Flood History

With that background let us look at some of the historic floods. The first is the big one of March 1907. It was a monster flood, with huge outflows of water from the mountains —beyond what anyone had experienced except the few old folks who could remember the legendary inundations of 1862, 45 years earlier.

There had been a 50-year debate over what to do for flood control in the Sacramento Valley. A smaller flood (about half as big as 1907) in 1904 was a wake-up call and stimulated much flood control planning activity. In 1905, in cooperation with the U.S. Geological Survey, the State of

1 Standard project flood refers to a return period of more than 1 in 200 years.

California began to put in stream gages to measure flow in the Central Valley. In 1904, a commission of leading river engineers was appointed, headed by Major T. G. Dabney, a distinguished U.S. Corps of Engineers engineer with 20 years experience in the lower Mississippi River. Relying on that experience, the Dabney Commission rejected the concept of bypasses and recommended that the Sacramento River be confined within levees (wider apart than the present ones) that would allow it to carry 250,000 cubic feet per second. The main river channel would then scour, helping to restore navigability. The report was published in 1905, and the "powers that be" set out to construct the plan as a joint local-state-federal project.

Then, in 1907, the flood struck. The Feather River burst out of its banks a few miles south of Oroville to rush southwesterly, north of Sutter Buttes, and poured into the Sacramento River above and below the town of Colusa, overwhelming levees and inundating much of the land between the Sacramento and Feather rivers. In all, 300,000 acres was flooded in the Sacramento Valley. By the time the Geological Survey got through analyzing its records, they found that about 600,000 cfs had poured out of the Sacramento River into Suisun Bay.

Two years later, in January 1909, another large flood reinforced this conclusion, with a comparable 3-day volume but not as high an instantaneous peak, at least on the Feather River. This record flood removed lingering doubts about the design flood for the Sacramento River Flood Control Project. It was fortunate that these floods happened before the Dabney Report's project could be constructed; it would have been mostly wasted money.

A gifted engineer, Thomas H. Jackson, from the Corps of Engineers, became a leading spirit in the California Debris Commission. Captain Jackson and the Debris Commission got right to work and produced a new plan in 1910, which included overflow weirs and bypasses. This plan has become the Sacramento River Flood Control Project (Figure 4). At the latitude of Sacramento, it can handle about 600,000 cubic feet per second — 110,000 in the Sacramento River and 500,000 in the Yolo Bypass, with the design based largely on a blend of the 1907 and 1909 flood events. This design has served well, including the monster 1986 flood. Remember, however, that the plan did not include flood control reservoirs in the foothills — but was built to contain the largest expected flood — maybe about 50-year flood protection. The big flood control reservoirs were added later to further improve protection.

After 1909, no really big regional flood seems to have occurred until the 1950s. There was a moderate-sized flood in March 1928, another in December 1937, and again in late-February 1940. Those from San Diego County may remember the January 1916 floods, supposedly set off by rainmaker Charles Hatfield. Also, I believe 1938 was impressive in the coastal mountains of Los Angeles County.

But we have to move to water year 1951, specifically November 1950, to see a resurgence of heavy southwesterly-origin downpours. This storm was especially heavy in the southern Sierra (with 91,000 cfs peak flow on the Kings River east of Fresno) and was further impetus to complete the four Tulare Lake Basin flood control reservoirs from the Kings to Kern rivers: Pine Flat, Terminus (Lakd Kaweah), Success, and Isabella reservoirs (and also Folsom Reservoir on the American River near Sacramento). The 1950 storm was not particularly impressive in the northern Sacramento Valley. Pine Flat and Isabella dams were completed in 1954; Folsom in 1956 (but the dam was ready for flood control in 1955), and Success and Terminus dams were completed in 1961 and 1962.

As several of these new flood control projects became operational, an even larger flood was unleashed a few days before Christmas 1955. The storm ranged over most of the central and northern part of California from Bakersfield to the Oregon border. It was larger than the 1907 flood on the upper Sacramento and American rivers, but not quite as big on the Feather River. The North Coast was hit heavily, with the greatest flow of record (to that time), 541,000 cfs, on the Eel River. A break in the Feather River levee at Yuba City caused 38 deaths.

Nine years later, in December 1964, a still bigger flood hit. Again a large area was affected, from about Fresno northward into coastal Oregon. The runoff of the North Coast rivers was enormous, with a peak flow shooting past the 1955 record to around 750,000 cfs on the Eel River at Scotia. The area was devastated. Three-day runoff on the Feather River exceeded the 1907 peak and the nearly comparable 1955 peak, with a 3-day flow rate of 165,000 cubic feet per second, but the partially completed Oroville Dam reduced the peak and undoubtedly prevented severe flood damage in the Sacramento Valley.

Except for the December 1966 intense flood in the southern Sierra, most of the middle part of California had a respite for two decades. But 1969 was a very wet water year, with a large snowmelt flood on the San Joaquin River from a snowpack that was 210% of average statewide on April 1. Santa Barbara County also saw amazing record flows of 80,000 cfs on the Santa Ynez River near Lompoc in January of that year.

In January 1970 and the same month in 1974 we saw a pair of very large floods on the upper Sacramento River, with 3-day unimpaired flow rates exceeding 200,000 cfs near Red Bluff. These appear to be the largest floods of record here, slightly exceeding the December 1964 event and another large flood in 1940, and definitely more than the 1907 flood on which the system design was patterned. But these two floods were upper Sacramento floods and, although large, were not unusual on other northern California rivers.

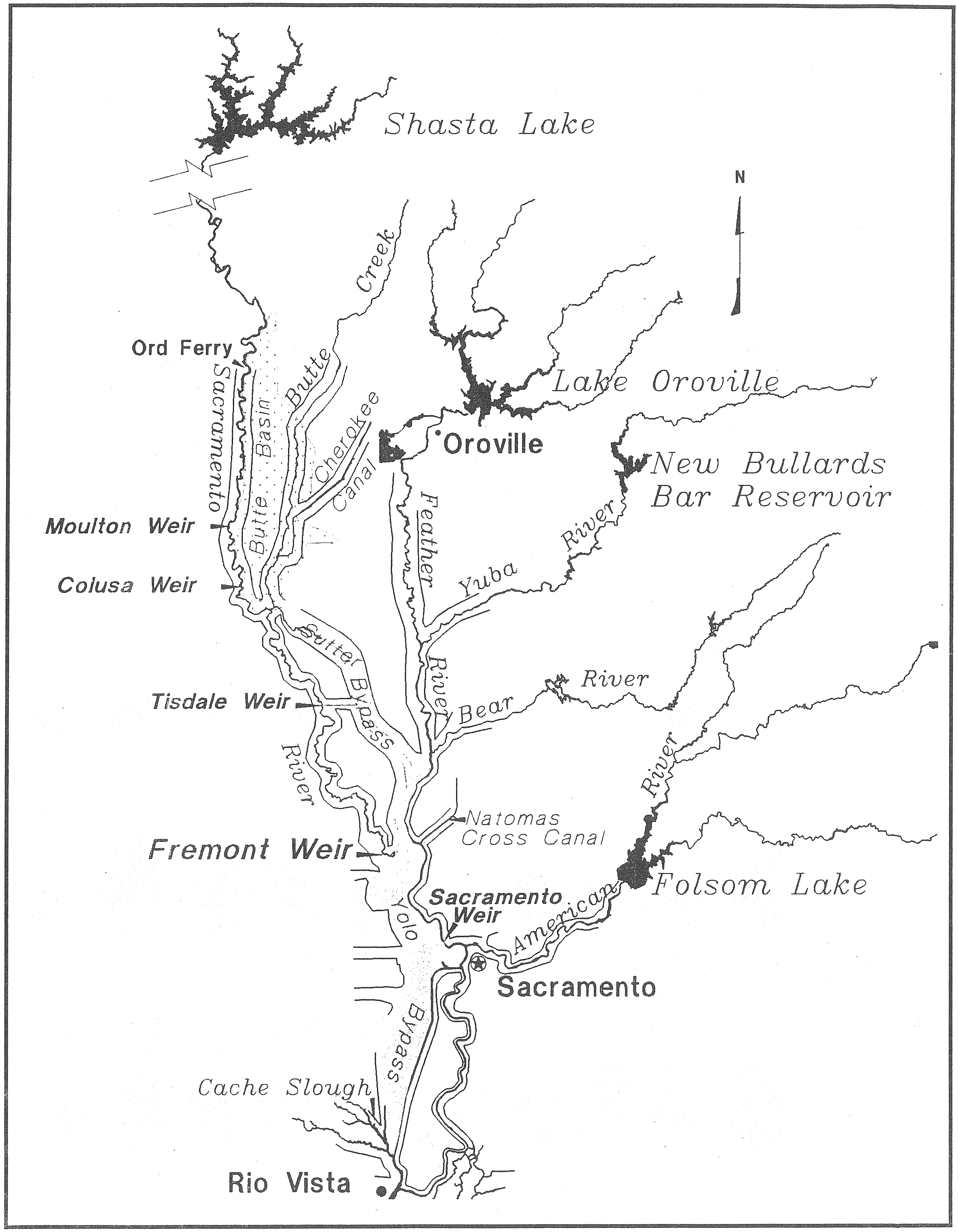

Figure 4. Sacramento River Flood Control System

Water year 1983 was the wettest this century, but did not produce any major river floods, although rivers ran high for an extended period. Once again, the high Sierra accumulated an enormous snowpack, over twice average. But shrewd operation of the reservoir system averted major snowmelt flood damage. Tulare Lake even became California's largest fresh water body again for a short time.

Now we come to the big one for the north-central part of California — the February 1986 flood. Until nearly the middle of February in that water year, conditions were a little drier than average. Then we got about a half-year's precipitation in 10 days. Again it was a classical warm, subtropical southwesterly flow situation. The heaviest rain areas were from the northern San Francisco Bay area across the central Sierra. Although flooding occurred on the North Coast and on the upper Sacramento River, floods were not unusually large in those regions. The Eel River, for example, peaked at 364,000 cfs. But the sheer volume of flow in the mid-Sierra from the Feather River on down through Mokelumne River was astounding, as shown by flood size comparisons (Figure 5). (The 3-day floodflow rate is shown because that time period better indicates the need for foothill reservoir flood control storage.)

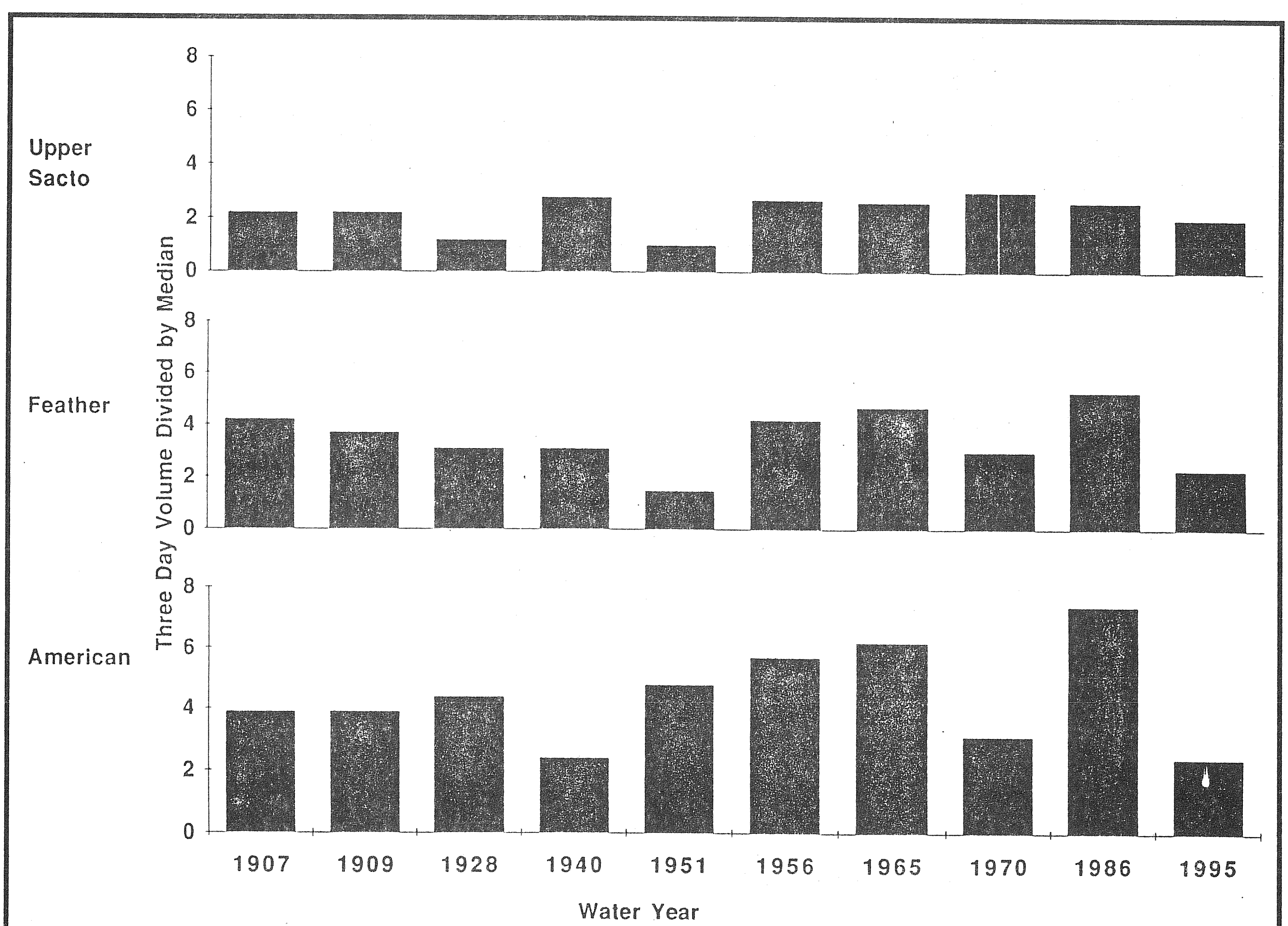

Figure 5. Comparison of Flood Sizes to Median

The lower Sacramento River floodway system was taxed to near design levels. In fact, Fremont Weir and Yolo Bypass stages actually went over design. Once again the American River was shown to be bigger than expected (Figure 6) leading to proposals for more flood control. A few hours more of the steady rain of 0.3 inch per hour on the watershed could have been disastrous to the Sacramento area.

From there, the scene shifted into drought, and it was 1995 before significant high water recurred. However, the 1995 floods were not that big on the major rivers of northern California, except near the coast. The Russian River approached its 1986 peak in January, and the Napa River reached a new peak of record in March. The real surprise was the Salinas River, which crested at 30.3 feet near Spreckels and exceeded the 1952 record of 26.2 feet by about 4 feet in March. This was within 1 or 2 feet of the estimated stage of 31 to 32 feet back in the legendary 1862 flood — long before Nacimiento and San Antonio dams were built. The Pajaro River, while exceeding its flood stage of 32 feet at Chittenden gage, did not quite reach the peak of record, 33.1 feet, set in 1958. Arroyo Pasajero flows near Coalinga, which collapsed the Interstate-5 crossing, probably were close to a 100-year event.

Conclusion

There you have the 10 biggest California floods of this century. There seems to be a trend for bigger events. Is it real? We would like to be sure we are not under-designing, but large water and flood control projects are costly.

There are always strange quirks. Water year 1996 was not especially noteworthy in the flood department, mostly a "normal" year. But during a west-northwest flow pattern with relatively high pressure at the end of December 1995, we saw the Mad River near Arcata (in the Eureka area) rise above flood stage for the highest level since the big North Coast flood of 1964. Stay tuned, be alert, be prepared!

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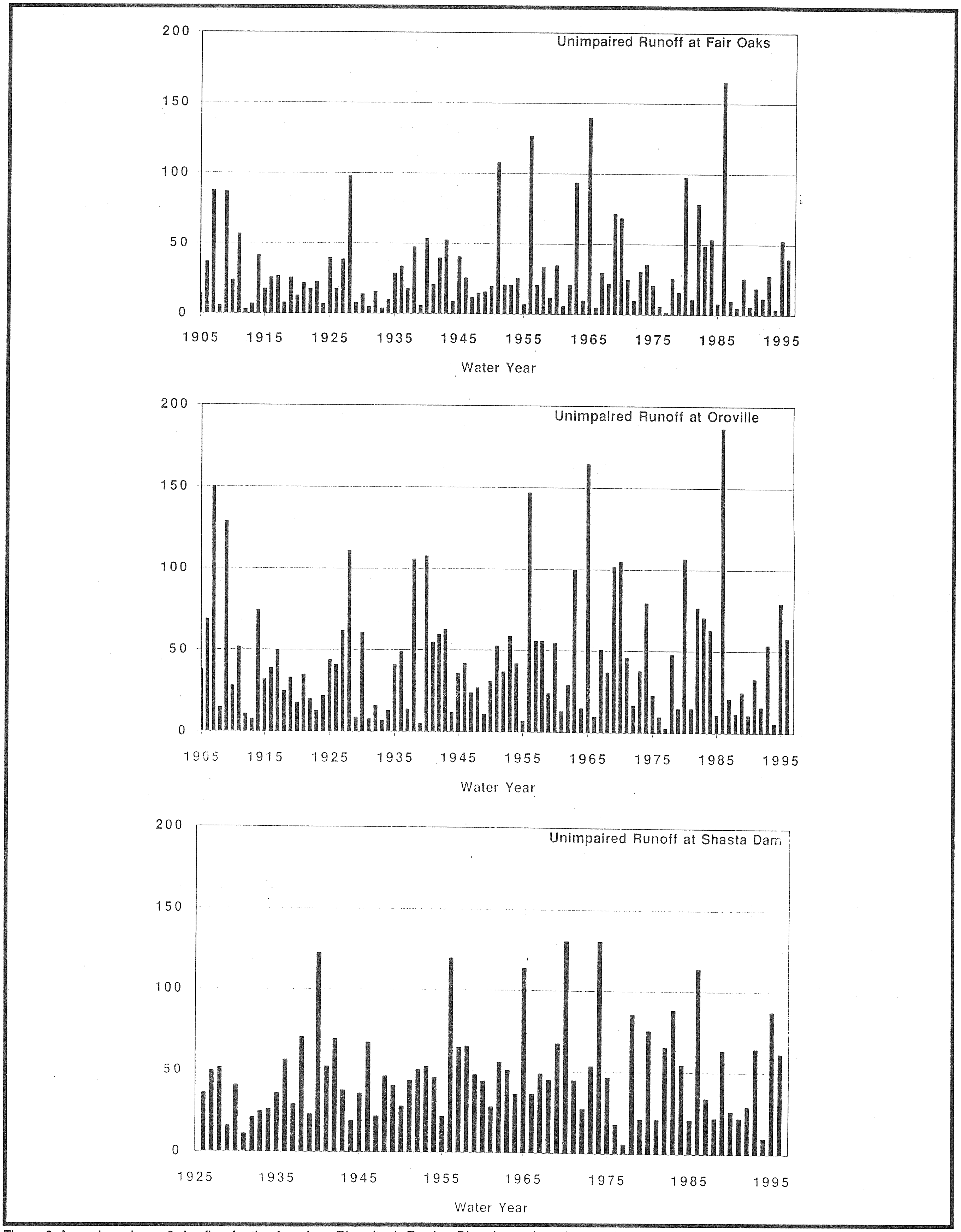

Figure 6. Annual maximum 3-day flow for the American River (top), Feather River (center), and upper Sacramento River (bottom).
Flow is expressed as 1,000 cubic feet per second.